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An estimation approach for uncertain parameters in multibody systems.

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Abstract

In the design of mechanical systems there are often parameters which are uncertain. This could be due to tolerances (e.g. dimension of a given component) or because they are dependent on many difficult to predict variables (e.g. joint friction). However in order to monitor the performance or control these systems robustly, it could be very important to have accurate knowledge of these a-priori uncertain variables. One possibility to obtain the values for these parameters, is performing direct measurements on the machine. However, this is not always a solution. For many variables there is no direct measurement method. Even if it is possible to measure a given parameter, it could still be highly dependent on operational conditions, causing it to vary constantly. In order to allow a reliable assessment of these uncertain parameters in operational conditions, indirect methods have been developed which allow online monitoring.

Indirect measurements allow extracting information from measuring easily accessible variables (e.g. accelerations) and a suitable relation with the variable of interest. In virtual measurements this relationship is provided by a virtual model of the system. One of the most successful methods in this framework is the Kalman filter (KF) [6]. This method was originally developed for state-estimation of linear dynamical systems, and nonlinear variations like the extended Kalman filter have been around for decades. More recently this approach has also been applied to the state-estimation problem for multibody system [1] and the coupled state/input estimation of multibody systems [4]. The Kalman filter also enables the estimation of uncertain parameters, if these are added as augmented states [5]. In this case a simple random walk model has to be assumed for the unknown parameter p:

$$\dot{p} = 0 \cdot p + r_p. \tag{1}$$

In this equation, r_p is the uncertainty on how fast a parameter can vary over time, which is typically rather low. In order to enable real-time estimation of variables however, highly efficient models need to be employed. For this purpose model order reduction is performed.

This work proposes the use of the augmented extended Kalman filter (A-EKF) coupled with a reduced multibody model to get estimates for uncertain parameters in the model. The A-EKF is inherently suitable for online nonlinear applications due to its time-based description. However, this approach only works for ordinary differential equations. In order to get the multibody equations of motion in a suitable form Global Modal Parameterization, a system level nonlinear model reduction technique, is applied [2, 3]. However, this method does not allow parameter dependency, and for this aim the approach is coupled with a parametric model order approach. By approximating the parameter dependency by an affine function (interpolation) it is relatively straightforward to compute the derivatives for the parameters in comparison to the unreduced model.

The proposed methodology is validated through a flexible slider crank mechanism. Two different cases are presented:

- Uncertain friction parameters for the slider. In this case there is a linear dependence on the uncertain parameter and a regular GMP model can be used due to the linear parameter dependence.
- Uncertainty on the section of the crank. In this case there is a nonlinear dependence on the uncertain parameter and a parameterized GMP model needs to be employed.

These examples show that the proposed approach is capable of providing good estimates of uncertain parameters for multibody systems. By exploiting model reduction techniques the computational load is sufficiently low for online applications.

References

[1] Cuadrado, J.; Dopico, D.; Barreiro, A.; Delgado, E.: Real-time state observers based on multibody models and the extended Kalman filter. Journal of Mechanical Science and Technology, Vol. 23, No. 4, pp. 894-900, 2009

[2] Naets, F.; Heirman, G.; Vandepitte, D.; Desmet, W.: Inertial force term approximations for the use of Global Modal Parameterization for planar mechanisms. International Journal for Numerical Methods in Engineering, Vol. 85, No. 4, pp. 518–536, 2010.

[3] Naets, F.; Tamarozzi, T.; Heirman, G.; Desmet, W.: Real-time flexible multibody simulation with Global Modal Parameterization. Multibody System Dynamics, Vol. 27, No. 3, pp. 267–284, 2012.

[4] Naets, F.; Pastorino, R.; Cuadrado, J.; Desmet, W.: Online state and input force estimation for multibody models employing extended Kalman filtering. Multibody System Dynamics, DOI:10.1007/s11044-013-9381-8, 2013

[5] Naets, F.; Croes, J.; Desmet, W.: Online state and input force estimation for multibody models employing extended Kalman filtering. Computer Methods in Applied Mechanics and Engineering (submitted)

[6] Simon, D.: Optimal State Estimation: Kalman, H_∞ and nonlinear approaches, New York: J. Wiley and Sons, 2006.